UNIVERSITY OF CALIFORNIA
COLLEGE OF AGRICULTURE
AGRICULTURAL EXPERIMENT STATION
BERKELEY, CALIFORNIA

# VARIETAL SUSCEPTIBILITY TO COMMON BEAN MOSAIC AND TRANSMISSION THROUGH SEED

FRANCIS L. SMITH AND WM. B. HEWITT

---

BULLETIN 621

MAY, 1938

UNIVERSITY OF CALIFORNIA
BERKELEY, CALIFORNIA

# CONTENTS


| | PAGE |
|---|---|
| Introduction | 3 |
| Experimental methods | 3 |
| Inoculation methods used | 3 |
| Planting and inoculating varieties in the field | 4 |
| Classification of varieties according to symptoms | 4 |
| Transmission of common bean mosaic through the seed | 6 |
| The relation between symptoms and seed transmission | 9 |
| The effect of temperature on the symptoms displayed in bean plants | 10 |
| Discussion | 11 |
| Summary and conclusions | 11 |
| Literature cited | 13 |

# VARIETAL SUSCEPTIBILITY TO COMMON BEAN MOSAIC AND TRANSMISSION THROUGH SEED[1]

FRANCIS L. SMITH[2] AND WM. B. HEWITT[3]

## INTRODUCTION

COMMON BEAN MOSAIC, a disease caused by a virus, is prevalent in many bean-growing areas in California. One of its methods of dissemination is through the seed, which bridges the gap from one generation to the next. Control of the disease in a susceptible variety is through production of clean seed; this requires eternal vigilance in the removal of diseased seedlings. If this roguing is done early in the season, it will also prevent the spread of the disease by insect vectors to healthy plants. This bulletin reports experiments inaugurated to determine the relation between severity of infection and the extent to which the disease is seed-borne.

The ultimate control, however, will be best achieved by producing strains and varieties which are resistant to the disease. A great deal of work has been done in testing the susceptibility of varieties; a number of mosaic-resistant strains have been found, and others are being developed.

In order to find resistant lines for future breeding stock, the strains most commonly grown in California were compared with those of other states; this also provided a wide range of varieties for the seed-transmission studies reported in the present paper. Incidentally, observations of the effect of temperature on the expession of symptoms were noted.

## EXPERIMENTAL METHODS

*Inoculation Methods Used.*—The preliminary testing of various methods (*3, 12, 15, 19*)[4] for mechanically transmitting common bean mosaic was carried out in the greenhouse. Of the methods tried, the carborundum method described by Rawlins and Tompkins (*15*) proved to be the most satisfactory. To further test the method, 95 selections of beans representing 35 varieties were tested. Of the total plants inoculated, about 96 per cent became infected. In 81 of the selections, 100 per cent of the plants inoculated became infected, and in the remaining 14 selections, 80 per cent.

The method was slightly modified as follows for the large number of field inoculations. A swab for the application of the juice inoculum from diseased plants to the healthy plants was prepared by padding the end of a pot label with cotton and covering this with a layer of cheesecloth.

[1] Received for publication October 18, 1937.

[2] Junior Agronomist in the Experiment Station.

[3] Junior Plant Pathologist in the Experiment Station.

[4] Italic numbers in parentheses refer to "Literature Cited" at the end of this bulletin.

The inoculum was prepared by grinding young, diseased bean plants in a food chopper and pressing the juice from the pulp through a cheesecloth filter. Powdered carborundum, 600-mesh, was added directly to the juice instead of sprinkling it on the leaves to be inoculated as described by Rawlins and Tompkins. The carborundum powder served as an abrasive on the leaf surface. This modification increased the rapidity of inoculation and conserved the powder. The juice was stirred at the time of each application with the swab to insure a thorough distribution of the carborundum. From two to three leaflets were inoculated on each plant.

*Planting and Inoculating Varieties in the Field.*—Common bean mosaic is readily transmitted through the seed, and apparently the other viruses of the bean are not and consequently may be eliminated from consideration in this way (*6, 12, 18, 21*). Those plants infected early or which have carried the mosaic through the seed will produce some infected seed, the percentage depending somewhat on the variety; whereas those which become infected during full bloom or later very seldom transmit mosaic through the seed (*4, 5, 6, 11*). In plants infected early with mosaic, the seed from the first flowers seem to carry a higher proportion of disease to the progeny than those which are borne later (*4, 5*).

For the test plants a number of bean varieties were planted at Berkeley in June, 1935, in rows 40 feet long and 33 inches apart. This provided enough space for about 100 plants in each row.

The inoculum was prepared from young Otenashi bean plants, planted three weeks earlier, which had carried the mosaic through the seed. These plants were ground and the juice extracted, as they were needed for inoculation.

The plants were inoculated June 21 when the majority had developed the first set of trifoliate leaves. Inoculation at this time was considered best because the plants of all varieties, early and late maturing, were about the same stage of growth and the selections could be compared as to their relative susceptibility. This also gave a uniform time of inoculation for seed-transmission studies (*4, 6, 12*) in order to guard against factors related to differences in maturity.

Three weeks after inoculation the plants were examined and all of the varieties known to be suseeptible were found to be 100 per cent infected.

## CLASSIFICATION OF VARIETIES ACCORDING TO SYMPTOMS

Bean varieties have been grouped according to their susceptibility to bean mosaic by a number of workers (*3, 12, 14, 16, 17*). Any system of grouping, however, is more or less relative and can be based only on external symptoms. The placing of varieties in groups depends largely on the individual's judgment of the symptoms displayed. There is considerable evidence to show that the symptoms may vary with the environment so that varieties grown in one locality may differ in their display of symptoms when grown in another (*1, 2, 5, 7, 9, 13*). Also there may be a great degree of variation in the type of mosaic symptoms within plants of the same variety grown at the same time under the same conditions. This was most pronounced in the Red Kidney bean plants and was evident in other varieties grown both at Berkeley and Davis. Plate 1 and

plate 2, *E* and *G*, show some of the variations in symptoms found among the plants of Red Kidney beans in the two plots.

Common bean mosaic may be recognized in the simple leaves of infected seedling beans by a mottling of dark and light-green areas in the lamina. Only one of the leaves may show the mottling or in some cases the entire leaf may have a lighter color when compared with those of healthy plants. Often the edges of the simple leaves are curled slightly downward, which arches the leaf.

As the plants develop, the compound leaves generally show symptoms which are much more striking than the simple leaves. The mottling occurs in various patterns over the leaf (plates 1, 2, 3). Commonly, however, the background is a light green with dark-green areas varying in size from large to very small interspersed over the leaf (plate 2). The dark-green areas often appear as bands around the mid and lateral veins (plate 2, *B* and *D*). In some varieties the dark areas appear as blisters on the surface and may become "savoyed" (plate 3, *C*, *F*, *G*, and *H*). In other varieties the entire leaf may become wrinkled (plate 3, *E*). Other leaves may develop with only a light color but the surface frequently appears leathery. The leaflets are frequently elongated at the tip and attenuated at the base (plate 1, *C* and *F*). One of the symptoms common to most varieties studied and which appears to be a constant feature of mosaic is the curling downward of the margins, resulting in an arching of the upper surface and a cupping of the ventral side of the leaflets (plate 1, *B*, *C*, and *G*, and plates 2 and 3).

Various degrees of dwarfing of the leaves and plants also occur (plate 4, *A*, *B*, *E*, and *F*).

About 3 weeks after the plants were examined for mosaic infection, notes were taken on the relative severity of the mosaic as displayed in the external symptoms of the varieties.

In classifying the varieties for relative susceptibility to mosaic, five groups were recognized by the authors in an arbitrary classification. These classes were based on the symptoms shown by the leaves and by the general vigor of all the plants within the row as compared with healthy plants of the same variety. The symptoms displayed by each class are as follows:

Class 0. No symptoms: The plants in this class showed no apparent symptoms. (The plants were not tested to see if they were symptomless carriers of the virus.)

Class 1. Slight symptoms: In this class the plants showed only a weak display of symptoms. They were vigorous and apparently not greatly injured by the virus (plate 4, *F*). The leaflets were slightly attenuated at the base, showed a small amount of mottling (plate 2, *B* and *D*) and were frequently cupped slightly downward (plate 1, *D*).

Class 2. Moderate symptoms: The plants in this class showed a greater degree of symptom expression than those of class 1. The leaflets were generally slightly puckered and attenuated at the base (plate 1, *E* and *F*, and plate 2, *F* and *H*). They showed considerable downward cupping (plate 1, *C* and *G*) and often showed a dispersed type of mottling (plate 1, *E*, and plate 2, *F* and *H*).

Class 3. Severe symptoms: In this class the plants were definitely dwarfed by the virus (plate 4, *E*). The leaflets were usually badly cupped and severely mottled as in plate 1, *B*, and plate 2, *E* and *G*. Others were severely puckered and some of them had green blisterlike projections on the surface (plate 2, *C*, and plate 3, *B*, *C*, and *E*).

Class 4. Very severe symptoms: The plants of this class were badly dwarfed and almost all were completely sterile (plate 4, *A* and *B*). The leaf symptoms were similar to those in class 3 and even more pronounced (plate 3, *D*, *E*, *F*, and *G*).

The seed from these varieties was harvested and stored for planting the next season to obtain the percentage of seed that carried mosaic.

## TRANSMISSION OF COMMON BEAN MOSAIC THROUGH THE SEED

The seed from the 1935 planting at Berkeley was made up in duplicate planting lists—one to be planted in Berkeley and the other in Davis. In both places the beans were planted in 40-foot rows about 36 inches apart. The Berkeley plots were planted May 28 and the Davis plots on June 2, 1936. Counts on the number of plants showing systemic infection, presumably seed-transmitted mosaic, were made in Berkeley, July 9 and in Davis, July 10. The results are given in table 1. Notes were taken on the

TABLE 1

MOSAIC TRANSMISSION THROUGH SEED OF INOCULATED PLANTS OF FIVE SEVERITY CLASSES, GROWN AT BERKELEY AND DAVIS

| Variety | Authors' accession No. | Row | Berkeley | | Davis | |
|---|---|---|---|---|---|---|
| | | | Number of plants | Per cent of seedlings infected | Number of plants | Per cent of seedlings infected |
| Class 0—plants with no symptoms | | | | | | |
| Hungarian Large White | 4404 | 42, 43 | 230 | 0.0 | 154 | 10.4 |
| Great Northern, University of Idaho No. 1 | 5614 | 47 | 79 | 0.0 | 70 | 0.0 |
| Great Northern, University of Idaho No. 59 | 5615 | 48 | 101 | 0.0 | 85 | 0.0 |
| Great Northern, University of Idaho No. 81 | 5616 | 49 | 94 | 0.0 | 86 | 0.0 |
| Michigan Robust | 4458 | 71 | 117 | 0.0 | 52 | 0.0 |
| Michigan Robust | 4517 | 72 | 103 | 0.0 | 99 | 0.0 |
| Michigan Robust | 4436 | 73 | 92 | 0.0 | 49 | 0.0 |
| Michigan Robust | 4561 | 74 | 109 | 0.0 | 85 | 0.0 |
| Michigan Robust | 4933 | 75 | 112 | 0.0 | 72 | 0.0 |
| Frijole Negros | 5033 | 91, 92 | 233 | 0.0 | 205 | 0.0 |
| Scotia, or Striped Creaseback | 5239 | 120 | 116 | 0.0 | 92 | 2.2 |
| Total or weighted average | | 13 | 1,386 | 0.0 | 1,049 | 1.7 |
| Class 1—plants with slight symptoms | | | | | | |
| Robusta | 7(32)27 | 50 | 105 | 6.7 | 80 | 0.0 |
| Bayo | 5004 | 93 | 114 | 4.4 | 91 | 0.0 |
| White Creaseback | 5071 | 113 | 75 | 10.7 | 16 | 12.5 |
| Total or weighted average | | 3 | 294 | 6.8 | 187 | 1.1 |

TABLE 1—(*Continued*)

| Variety | Authors' accession No. | Row | Berkeley | | Davis | |
|---|---|---|---|---|---|---|
| | | | Number of plants | Per cent of seedlings infected | Number of plants | Per cent of seedlings infected |
| Class 2—plants with moderate symptoms | | | | | | |
| Cranberry | 4471 | 1 | 115 | 7.0 | 90 | 22.2 |
| Cranberry | 4460 | 2 | 127 | 10.2 | 101 | 36.6 |
| Cranberry | .... | 4 | 97 | 2.1 | 96 | 21.8 |
| Cranberry | 5075 | 6 | 86 | 4.7 | 108. | 11.1 |
| Cranberry, black mottled | 5028 | 3 | 151 | 6.6 | 130 | 6.9 |
| Dwarf Horticultural | 5100 | 5 | 100 | 6.0 | 100 | 12.0 |
| London Horticultural | 5556 | 7 | 119 | 5.0 | 118 | 8.3 |
| Nagazura | 4390 | 8 | 93 | 12.9 | 115 | 26.1 |
| Nagazura | 4413 | 9 | 116 | 22.4 | 85 | 23.6 |
| Nagazura | 4463 | 10 | 95 | 19.0 | 35 | 28.5 |
| Nagazura | .... | 11 | 97 | 13.3 | 127 | 36.2 |
| Nagazura | 4442-1 | 12 | 81 | 7.4 | 91 | 14.3 |
| Nagazura | 4442-4 | 13 | 104 | 4.8 | 112 | 18.8 |
| Red Kidney | 4442 | 14 | 93 | 9.7 | 101 | 28.7 |
| Red Kidney | 4370 | 15 | 113 | 12.4 | 105 | 25.8 |
| Red Kidney | 4395 | 16 | 133 | 9.8 | 101 | 29.8 |
| Red Kidney | 4462 | 18 | 100 | 8.0 | 102 | 23.5 |
| Red Kidney | 4468 | 19 | 127 | 1.6 | 138 | 19.5 |
| Red Kidney | 5081 | 26 | 100 | 3.0 | 103 | 15.6 |
| Red Kidney, Geneva | 4387 | 17 | 83 | 6.0 | 100 | 19.0 |
| Red Kidney, Geneva | 4565 | 21 | 109 | 3.7 | 104 | 10.6 |
| Red Kidney, Geneva | .... | 24 | 108 | 5.6 | 113 | 9.7 |
| Red Kidney, Italian | 4473 | 20 | 112 | 7.1 | 132 | 17.3 |
| Red Kidney, Simpson's strain | 4565 | 22 | 102 | 6.8 | 109 | 20.2 |
| Red Kidney, Simpson's strain | .... | 23 | 117 | 6.0 | 84 | 21.4 |
| Red Kidney, Simpson's strain | .... | 25 | 107 | 5.6 | 108 | 17.6 |
| Dark Red Kidney | 17(17)29 | 27 | 104 | 5.8 | 105 | 17.2 |
| Dark Red Kidney | .... | 28 | 85 | 8.3 | 89 | 12.4 |
| Dark Red Kidney | 7(85)30 | 29 | 84 | 6.0 | 105 | 18.1 |
| Lady Washington | 41(79)30 | 53 | 86 | 7.0 | 78 | 10.3 |
| Boston Pea bean | 4486 | 77 | 88 | 4.5 | 52 | 9.6 |
| California Pink | 4436 | 78 | 94 | 11.7 | 91 | 11.0 |
| California Pink | 4427 | 79 | 88 | 8.0 | 112 | 21.7 |
| California Pink | 4592 | 80 | 94 | 24.5 | 119 | 25.2 |
| California Pink | 4121 | 81 | 114 | 29.8 | 114 | 26.3 |
| Pink Hopi | 4394 | 82 | 112 | 20.5 | 135 | 10.4 |
| Kentucky Wonder | 4448 | 103 | 113 | 3.5 | 87 | 13.8 |
| Kentucky Wonder | 5077 | 104 | 113 | 0.0 | 104 | 3.9 |
| Kentucky Wonder | 5562 | 105 | 111 | 32.4 | 80 | 6.3 |
| Kentucky Wonder Wax | 5564 | 106 | 103 | 25.2 | 83 | 8.4 |
| Kentucky Wonder | 5651 | 107 | 86 | 4.7 | 52 | 5.8 |
| Kentucky Wonder | 5652 | 108 | 79 | 3.8 | 50 | 4.0 |
| Kentucky Wonder | 5653 | 109 | 108 | 6.5 | 79 | 5.1 |
| Large White | 4493 | 39 | 80 | 21.3 | 70 | 41.5 |
| Hibred New York No. 1 | 4573 | 66 | 75 | 0.0 | 63 | 17.5 |
| White Kidney | 4516 | 30 | 107 | 1.9 | 36 | 22.2 |
| White Kidney | 4483 | 31 | 90 | 12.2 | 60 | 31.8 |
| New York Marrow | 4070 | 34 | 68 | 7.4 | 11 | 27.2 |
| Perry Marrow | 4932 | 35 | 76 | 7.9 | 20 | 25.0 |
| Perry Large White Marrow | 4564 | 36 | 44 | 4.5 | 16 | 18.8 |
| White Marrow (flat) | 5080 | 37 | 102 | 5.9 | 38 | 23.7 |
| Tender Green | 5086 | 111 | 79 | 6 3 | 70 | 40.0 |
| Pencil Pod Black Wax | 5096 | 115 | 109 | 0.9 | 75 | 22.7 |
| Navy bean | 5639 | 117 | 104 | 24.0 | 45 | 28.9 |
| Total or weighted average | | 54 | 5,381 | 9 4 | 4,747 | 20.8 |

TABLE 1—(*Concluded*)

| Variety | Authors' accession No. | Row | Berkeley | | Davis | |
|---|---|---|---|---|---|---|
| | | | Number of plants | Per cent of seedlings infected | Number of plants | Per cent of seedlings infected |
| Class 3—plants with severe symptoms | | | | | | |
| White Kidney | 4934 | 32 | 87 | 2.3 | 24 | 37.4 |
| Large White | 4431 | 40 | 95 | 31.6 | 68 | 42.7 |
| Great Northern | 4398 | 44 | 97 | 13.4 | 86 | 18.6 |
| Great Northern | 4432 | 45 | 99 | 23.2 | 82 | 25.6 |
| Great Northern | 4365 | 46 | 106 | 9.4 | 70 | 24.3 |
| Lady Washington | 38(79)30 | 51 | 116 | 25.8 | 67 | 32.8 |
| Lady Washington | 41(79)30 | 52 | 159 | 8.2 | 138 | 13.8 |
| White Navy | 4438 | 67 | 121 | 14.0 | 93 | 7.5 |
| Blue Pod | 4545 | 68 | 83 | 15.7 | 79 | 16.5 |
| Blue Pod | 4402 | 69 | 106 | 13.2 | 62 | 17.7 |
| Blue Pod | 4432 | 70 | 73 | 15.1 | 57 | 10.4 |
| Isbell's Improved Dwarf Pea bean | 4481 | 76 | 122 | 31.2 | 98 | 30.6 |
| Mexican Red | 4425 | 83 | 150 | 16.0 | 134 | 29.0 |
| Mexican Red | 4399 | 84 | 136 | 13.2 | 130 | 17.5 |
| Mexican Red | 4434 | 85 | 130 | 12.3 | 119 | 15.1 |
| Mexican Red | 4331 | 86 | 142 | 9.9 | 117 | 13.7 |
| Mexican Red | 4437 | 87 | 81 | 12.4 | 113 | 20.4 |
| Mexican Red | 4386 | 88 | 136 | 13.3 | 129 | 20.2 |
| Mexican Red | 4368 | 89 | 127 | 11.8 | 125 | 20.0 |
| Mexican Red | 4947 | 90 | 115 | 19.1 | 86 | 36.1 |
| Bayo | 4405 | 94 | 122 | 15.6 | 105 | 10.5 |
| Bayo | 4541 | 95 | 128 | 13.3 | 102 | 16.7 |
| Bayo | 4416 | 96 | 119 | 29.6 | 100 | 15.0 |
| California Pinto | 4403 | 97 | 90 | 18.9 | 94 | 29.8 |
| California Pinto | 5047 | 101 | 122 | 36.1 | 109 | 33.0 |
| Idaho Pinto | 4369 | 99 | 111 | 32.4 | 127 | 39.4 |
| Idaho Pinto | 4440 | 100 | 113 | 39.8 | 108 | 42.6 |
| Large Pinto | 4390 | 98 | 98 | 36.8 | 98 | 22.5 |
| Large Pinto | 5050 | 102 | 101 | 59.4 | 90 | 38.9 |
| Extra Early Red Valentine | 5083 | 110 | 102 | 21.6 | 102 | 20.6 |
| Burpee's Stringless Green Pod | 5090 | 112 | 98 | 14.3 | 73 | 22.0 |
| McCaslan | 5079 | 114 | 72 | 6.9 | 55 | 7.3 |
| Stringless Green Pod Refugee | 5559 | 116 | 117 | 10.3 | 125 | 20.8 |
| Large White | 4493 | 38 | 99 | 59.6 | 64 | 43.7 |
| Hungarian Large White | 4404 | 41 | 68 | 10.3 | 88 | 21.6 |
| Total or weighted average | | 35 | 3,841 | 20.3 | 3,317 | 23.3 |
| Class 4—plants with very severe symptoms | | | | | | |
| New York Marrow | 4520 | 33 | 81 | 44.5 | 56 | 66.1 |
| Otenashi | 4388 | 54 | 103 | 70.6 | 43 | 48.8 |
| Otenashi | 4412 | 55 | 122 | 75.4 | 81 | 45.7 |
| Otenashi | 4469 | 56 | 128 | 51.6 | 73 | 41.1 |
| Kotenashi | 4401 | 57 | 102 | 23.5 | 67 | 19.4 |
| Kotenashi | 4401-a | 58 | 118 | 43.2 | 58 | 36.2 |
| Kotenashi | 4411-a | 59 | 111 | 26.2 | 63 | 22.3 |
| Small White | 4400 | 60 | 127 | 37.0 | 80 | 56.2 |
| Small White | 4421 | 61 | 107 | 11.2 | 75 | 25.4 |
| Small White | 4421 | 62 | 118 | 11.0 | 111 | 29.8 |
| Small White | 4546 | 63 | 99 | 25.2 | 99 | 15.2 |
| Small White | 4396 | 64 | 83 | 20.5 | 73 | 13.7 |
| Small White | 4433 | 65 | 96 | 18.8 | 91 | 7.7 |
| Total or weighted average | | 13 | 1,395 | 36.1 | 970 | 30.4 |

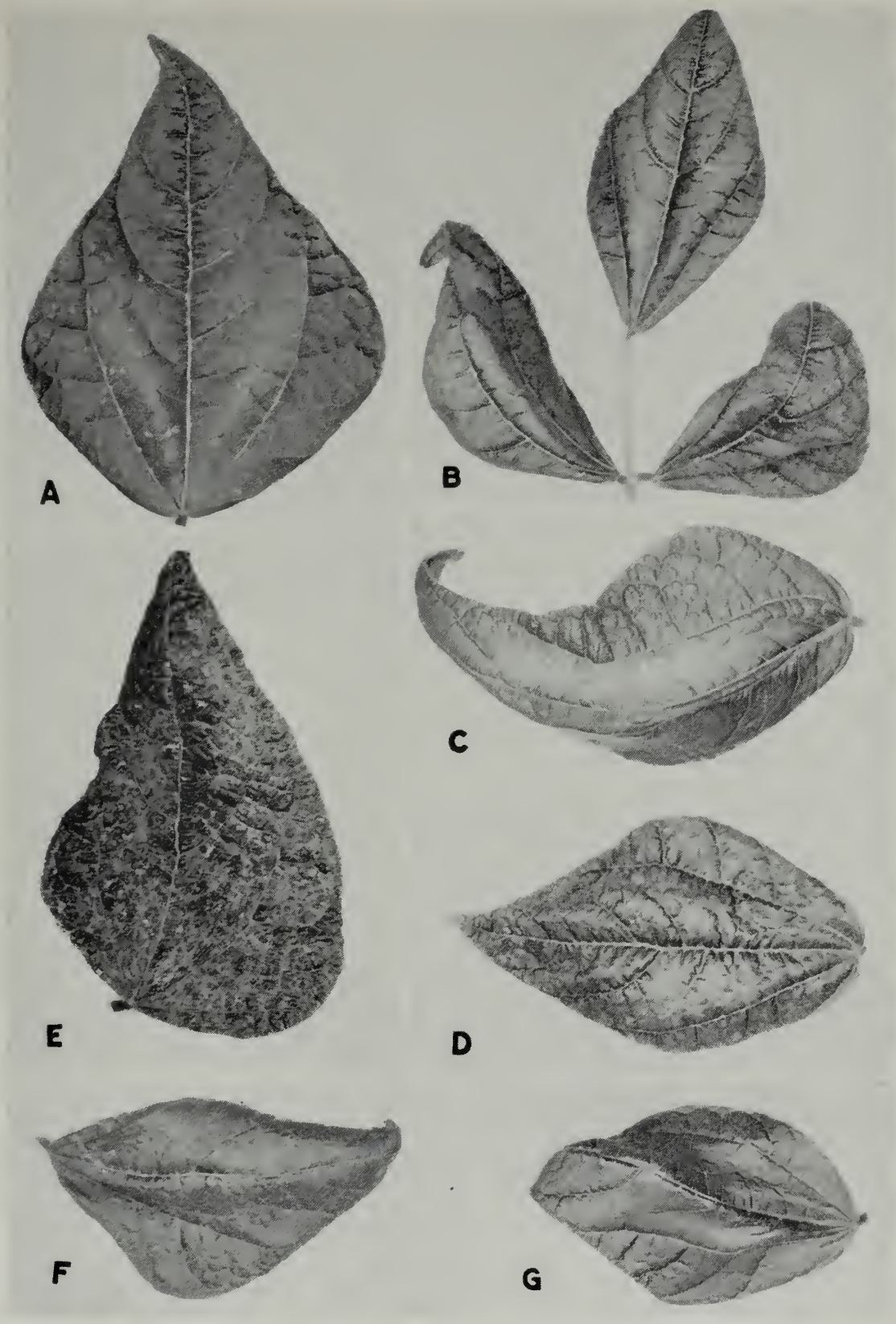


Plate 1.—Leaflets of Red Kidney bean showing wide variation in their display of common bean-mosaic symptoms: *A*, healthy leaflet; *B*, a leaf with each leaflet severely cupped and attenuated at its base and light in color except close around the larger veins (in the field the upper surface appears leathery); *C*, badly cupped, only the center sector showing disease symptoms, whereas the outer margins appear to be normally developed; *D*, cupped, with considerable puckering of the surface, but not showing any mottling; *E*, finely dispersed type of mottling, the shape being nearly normal; *F*, similar type of mottling as in *E* but the leaf is cupped and attenuated at the base; *G*, badly cupped with a smooth surface.

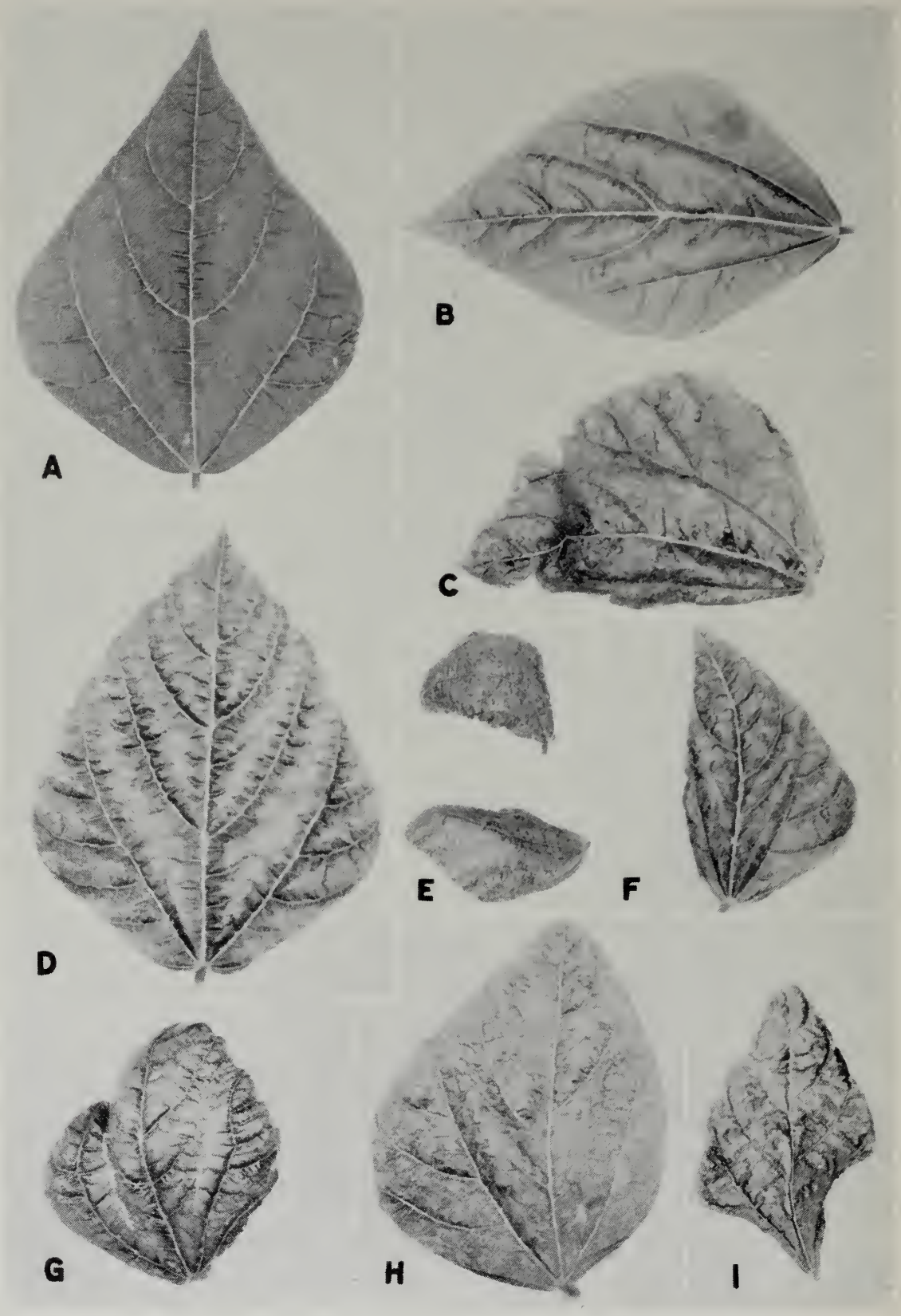


Plate 2.—Variation in the symptoms of common bean mosaic in the leaflets of different varieties of beans: *A*, Cranberry variety, healthy; *B*, Cranberry, with the normal green color confined to the large veins and the leaflet slightly attenuated at the base; *C*, Pencil Pod wax variety, severely cupped, puckered, and mottled, with green blisters on the surface; *D*, Cranberry, normal shape with clearing only between veins (compare with *B*); *E*, Red Kidney, dwarfed and severely cupped, with dispersed mottling (refer to other types of symptoms shown in plate 1); *F*, Cranberry, badly dwarfed, slightly cupped, and attenuated at the base; *G*, Red Kidney, very severely cupped and puckered, with normal green color only around the veins; *H*, Cranberry, nearly normal shape with a dispersed type of mottling; *I*, Cranberry, severely dwarfed, puckered, mottled, and badly drawn together at the base.

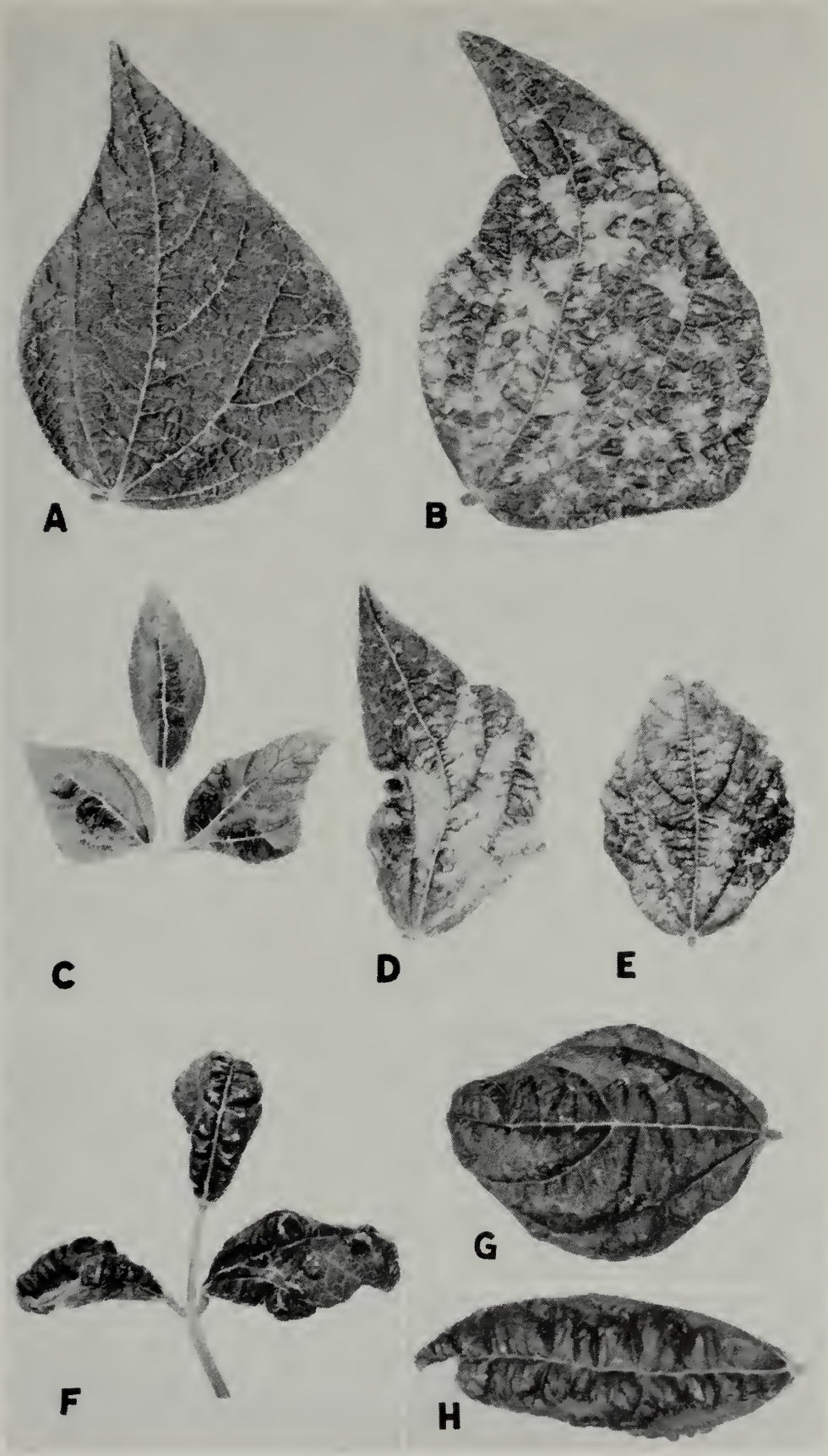


Plate 3.—Leaves and leaflets from bean plants showing symptoms of common bean mosaic: *A*, healthy leaflet of Nagazura variety; *B*, Nagazura leaflet of nearly normal shape but is severely mottled and a number of the affected cells apparently developed no chlorophyll, these areas appearing pale yellow in the field; *C*, leaf from Isbell's Improved Dwarf pea bean, severely dwarfed and mottled, with green blisters on the surface; *D*, Nagazura leaflet, attenuated at the base, curled at one side, and severely mottled; *E*, Nagazura leaflet with dispersed mottling and badly cupped; *F*, leaf of Isbell's Improved Dwarf pea bean showing very severe symptoms of mottling, cupping, and attenuation; *G*, *H*, also badly mottled leaflets of the same variety as in *F*.

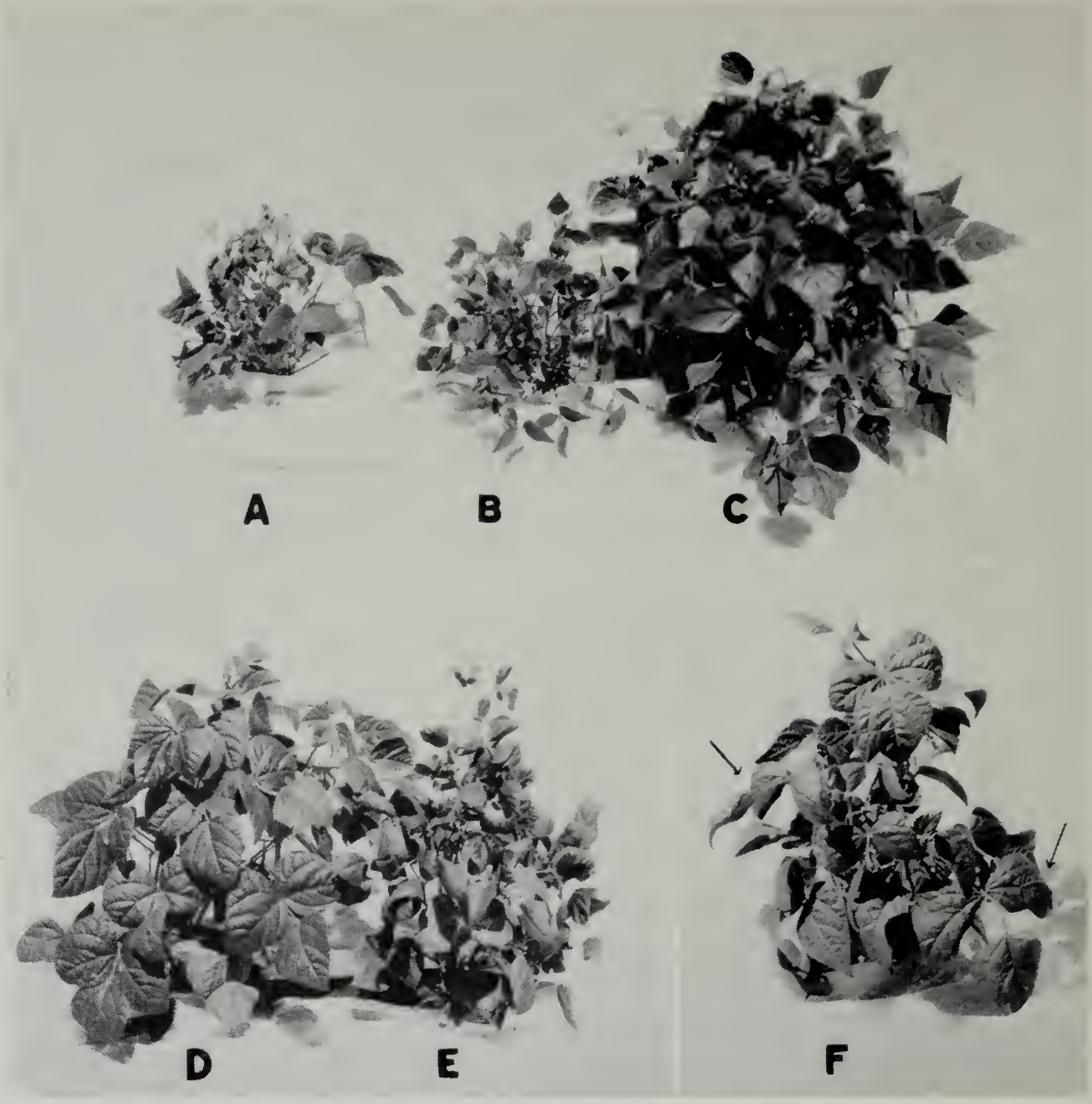


Plate 4.—*A*, *B*, *C*, Plants of the Small White variety, showing degrees of mosaic symptoms: *A*, severely dwarfed with badly mottled leaves, the plant having failed to set any pods; *B*, slightly less severe symptoms and bearing a few pods; *C*, healthy. *D*, *E*, *F*, Plants of the Red Kidney variety: *D*, healthy; *E*, severely affected with mosaic, the leaves being cupped downward and having leathery surfaces; *F*, slightly affected, only a few leaves showing typical mosaic symptoms, as indicated by arrows.

symptoms displayed by the different varieties about three weeks later. These readings were made on the same basis as those made in the Berkeley plots the previous year and described earlier in the paper. In general, the varieties were placed in the same mosaic group as the year before and none of them varied over a half class.

In most varieties there was a higher percentage of mosaic seedlings in the Davis planting. This may be attributed to early infections by aphids. When the counts were made, aphids were noted, and in one case there were as many as 5 aphids on a single plant. If the aphid infestation began early enough, this could account for the large number of mosaic-infected seedlings (*4, 6, 10, 20*). As further evidence for this supposition, a second count was made 10 days later. In the 107 rows which were susceptible there were 9,473 plants. On July 9 there were 2,070, or 21.9 per cent mosaic seedlings; and on July 19 there were 2,438, or 25.7 per cent mosaic seedlings. Thus 368 more plants developed symptoms during the 10-day interval. The incubation period for this disease is reported to be from 8 to 15 days (*4, 6, 13*), so that the plants in the second count might have been inoculated earlier than the date of the first count.

## THE RELATION BETWEEN SYMPTOMS AND SEED TRANSMISSION

Nelson (*11*) made the general statement that highly susceptible sorts, like the Refugee and many pea-bean varieties, transmit mosaic through the seed much more freely and regularly than the more resistant kinds of beans. The statement, however, apparently is based on observation only.

In order to measure the relation between the degree of susceptibility or severity of mosaic symptoms and the percentage of seed-borne mosaic (table 1), two correlation coefficients were calculated from the data. The percentages of seed-borne mosaic plants were grouped in intervals of 4 per cent. The mosaic classes used were grouped in five classes—0, 1, 2, 3, and 4. These classes were based on visual estimates as to the relative severity of the symptoms and were therefore arbitrary. For this reason too much confidence should not be placed in the values of the correlation coefficients that were obtained.

The results showing the distributions, the values of the means for each mosaic class, and the value of the correlation coefficient are given for the Berkeley and Davis data in table 2. The results at Davis indicate that some plants of supposedly resistant varieties had mosaic. Sixteen plants were found in a row of Hungarian Large White (No. 4404) in group 0. This variety has been under observation for three years. Three selections of this variety were tested. These three selections in 1936 were rows 41 in class 3 and 42 and 43 in class 0. As shown in table 1, row 41 had a mosaic class of 3, with 10.3 per cent seed-borne mosaic plants at Berkeley, and 21.6 per cent at Davis. It is therefore not surprising that row 43 should have some mosaic, inasmuch as the selection in this row was probably not yet homozygous for resistance and was still segregating some susceptible plants. Row 43, however, did not have any seed-borne mosaic at Berkeley and the mosaic class was 0. Both at Berkeley and Davis the selection in row 42 was immune and had no mosaic seedlings.

The other discrepancy was row 120 in class 0 in which Scotia (No.

5239) was grown. This selection has been under observation for a number of years. The occurrence of 2.2 per cent mosaic seedlings at Davis may have been due to the presence of hybrids resulting from natural field hybridization, which occurs frequently in California (*8*).

TABLE 2

DISTRIBUTION OF ROWS IN DIFFERENT INFECTION-PERCENTAGE GROUPS AND MOSAIC CLASSES OF PLANTS GROWN AT BERKELEY AND DAVIS

| Range groups of percentage of infection | Number of rows in each mosaic class at Berkeley | | | | | Number of rows in each mosaic class at Davis | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Class 0 | Class 1 | Class 2 | Class 3 | Class 4 | Class 0 | Class 1 | Class 2 | Class 3 | Class 4 |
| 72-75.9 | .. | .. | .. | .. | 1 | .. | .. | .. | .. | .. |
| 68-71.9 | .. | .. | .. | .. | 1 | .. | .. | .. | .. | .. |
| 64-67.9 | .. | .. | .. | .. | .. | .. | .. | .. | .. | 1 |
| 60-63.9 | .. | .. | .. | .. | .. | .. | .. | .. | .. | 1 |
| 56-59.9 | .. | .. | .. | 2 | .. | .. | .. | .. | .. | .. |
| 52-55.9 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. |
| 48-51.9 | .. | .. | .. | .. | 1 | .. | .. | .. | .. | 1 |
| 44-47.9 | .. | .. | .. | .. | 1 | .. | .. | .. | .. | 1 |
| 40-43.9 | .. | .. | .. | .. | 1 | .. | .. | 2 | 3 | 1 |
| 36-39.9 | .. | .. | .. | 3 | 1 | .. | .. | 2 | 4 | 1 |
| 32-35.9 | .. | .. | 1 | 1 | .. | .. | .. | .. | 2 | .. |
| 28-31.9 | .. | .. | 1 | 3 | .. | .. | .. | 5 | 3 | 1 |
| 24-27.9 | .. | .. | 3 | 1 | 2 | .. | .. | 6 | 2 | 1 |
| 20-23.9 | .. | .. | 3 | 2 | 2 | .. | .. | 10 | 8 | 1 |
| 16-19.9 | .. | .. | 1 | 3 | 1 | 1 | .. | 9 | 5 | 1 |
| 12-15.9 | .. | .. | 4 | 12 | .. | .. | 1 | 5 | 4 | 2 |
| 8-11.9 | .. | 1 | 7 | 6 | 2 | 1 | .. | 9 | 2 | .. |
| 4- 7.9 | .. | 2 | 24 | 1 | .. | .. | .. | 5 | 2 | 1 |
| 0- 3.9 | .. | .. | 8 | 1 | .. | 2 | .. | 1 | .. | .. |
| 0- | 13 | .. | 2 | .. | .. | 9 | 2 | .. | .. | .. |
| Total number of rows | 13 | 3 | 54 | 35 | 13 | 13 | 3 | 54 | 35 | 13 |
| Mean percentage in each mosaic class | 0 | 7.3 | 9.5 | 17.1 | 34.9 | 2.5 | 4.7 | 19.3 | 24.0 | 33.1 |
| Correlation coefficients and their standard deviations | Berkeley planting, .640±.054 | | | | | Davis planting, .608±.058 | | | | |

Unfortunately, the two plants in question were not tagged to see if they were actually hybrids from evidence which could have been obtained in the mature plants—such characters as seed size, seed shape, seed-coat color, and pattern of distribution.

## THE EFFECT OF TEMPERATURE ON THE SYMPTOMS DISPLAYED IN BEAN PLANTS

There is considerable evidence in the literature that the symptoms of mosaic diseases are greatly influenced by the environment (*3*). Dickson (*1*) reported that bean plants were infectious in a greenhouse at 60°–70° F, but that the symptoms were completely masked except in a few

old leaves; and Harrison (*5*) stated that the mosaic mottling was completely masked at both 59° and 86° F and very distinct at both 68° and 77°. The effects of temperature, light, and other environments have also been noted (*2, 5, 11, 19*).

The temperatures at Berkeley and Davis were compared for the time during which the bean plants were being observed. The maximum temperature at Davis varied from 106° to 109° F and at Berkeley from 76° to 80°. The mean temperature for Davis was from 70° to 76°, whereas at Berkeley it varied from 61° to 62°. The minimum temperature for Davis ranged from 42° to 48°, and that at Berkeley from 51° to 52°. The daily range at Davis varied from 49° to 53°, and at Berkeley from 22° to 26°.

Comparisons were made between the symptoms displayed in the various varieties grown at Berkeley and the same varieties grown at Davis. There was no marked difference noted in the symptoms of the varieties in the two localities, and in no cases were any of the varieties found to vary over a half class. Thus, temperatures around 100° F during the day, at Davis, apparently do not inhibit the formation of mosaic symptoms.

## DISCUSSION

From the results of the experimental work reported here, it is evident that in general the varieties most severely affected with mosaic produce a higher percentage of infected seed than those less affected with the disease. From observations, this may also be said about yield: Plants severely affected with mosaic produce lighter crops than those less affected by the disease and much less than do healthy plants. The loss in yield from the disease would depend on the number of mosaic plants. A few infected bean seedlings will serve as infection centers. It has been shown by Zaumeyer and Kearns (*20*) that only a small population of aphids will spread the disease to a high percentage of plants.

With these facts in mind it is suggested that the grower familiarize himself with the symptoms of the disease, some of which are shown in the plates in this paper. The mosaic plants should be removed from the fields as early as they can be recognized; this prevents spread to other plants, and reduces the amount of seed-borne transmission. Growers saving their own seed should rogue out the mosaic plants as many times as necessary to rid the field of disease before harvesting.

## SUMMARY AND CONCLUSIONS

Seedlings of 118 selections representing 51 varieties of common beans were artificially inoculated in field plots, and the seed harvested from the plants was planted at Berkeley and at Davis. The percentage of seed transmitting common bean mosaic for each selection is presented. The selections were arbitrarily classified into five classes according to the severity of symptoms.

The results indicate that there is a correlation between the severity of symptoms and the percentage of seed-borne mosaic from plants inoculated in the seedling stage. The average percentages of transfer at Berkeley for the mosaic classes 1 to 4, respectively, were: 6.8, 9.4, 20.3, and 36.1 per cent; at Davis the values were: 1.1, 20.8, 23.3, and 30.4 per cent.

The correlation coefficient between mosaic class and per cent seed-borne mosaic was .640±.054 at Berkeley, and .608±.058 at Davis. This indicates that the degree of severity of symptoms in the respective arbitrary classes represents the relative susceptibility of the varieties tested. If so, the symptom expressions may be used as a measure of the susceptibility.

The mean daily temperature at Berkeley during the months of the growing season was from 61° to 62° F, and that at Davis was from 70° to 76°; but there was no apparent difference in the display of symptoms in the two localities.

## LITERATURE CITED

1. Dickson, B. T.
1922. Studies concerning mosaic disease. MacDonald College Tech. Bul. 2:1–125.
2. Doolittle, S. P.
1921. Influence of temperature on the development of mosaic disease. Phytopathology 11:46–47.
3. Elmer, O. H.
1925. Transmissibility and pathological effect of the mosaic disease. Iowa Agr. Exp. Sta. Research Bul. 82:37–91.
4. Fajardo, T. G.
1930. Studies on the mosaic disease of the bean (*Phaseolus vulgaris* L.) Phytopathology 20:469–94.
5. Harrison, Arthur L.
1935. The physiology of bean mosaic. New York State Agr. Exp. Sta. (Geneva) Tech. Bul. 235:5–48.
6. Harrison, Arthur L.
1935. Transmission of bean mosaic. New York State Agr. Exp. Sta. (Geneva) Tech. Bul. 236:4–19.
7. Johnson, James.
1922. The relation of air temperature to the mosaic disease of potatoes and other plants. Phytopathology 12:438–40.
8. Mackie, W. W., and Francis L. Smith.
1935. Evidence of field hybridization in beans. Jour. Amer. Soc. Agron. 27: 903–10.
9. Merkel, Ludwig.
1929. Beiträge zur Kenntnis der Mosaikkrankheit der Familie der Papilionaceen. Ztschr. Pflanzenkrank. 39:289–347.
10. Nelson, Ray.
1922. Transference of the bean mosaic virus by *Macrosiphum solanifolii*. Science 56:342–44.
11. Nelson, Ray.
1932. Investigations in the mosaic disease of bean (*Phaseolus vulgaris* L.) Michigan Agr. Exp. Sta. Tech. Bul. 118:1–71.
12. Pierce, W. H.
1934. Viroses of the bean. Phytopathology 24:87–115.
13. Pierce, W. H., and C. W. Hungerford.
1929. Symptomatology, transmission, infection and control of bean mosaic in Idaho. Idaho Agr. Exp. Sta. Research Bul. 7:1–37.
14. Rands, R. D., and Wilbur Brotherton, Jr.
1925. Bean varieties for disease resistance. Jour. Agr. Research 31:101–54.
15. Rawlins, T. E., and C. M. Tompkins.
1936. Studies on the effect of carborundum as an abrasive in plant virus inoculations. Phytopathology 26:578–87.
16. Reddick, Donald, and V. B. Stewart.
1918. Varieties of beans susceptible to mosaic. Phytopathology 8:530–39.
17. Reddick, Donald, and V. B. Stewart.
1919. Additional varieties of beans susceptible to mosaic. Phytopathology 9: 149–52.

18. REDDICK, DONALD, and V. B. STEWART.
1919. Transmission of the virus of bean mosaic in seed and observations in thermal death-point of seed and virus. Phytopathology 9:445–50.
19. STEWART, V. B., and DONALD REDDICK.
1917. Bean mosaic. Phytopathology 7:61.
20. ZAUMEYER, W. J., and C. W. KEARNS.
1935. The relation of aphids to the transmission of bean mosaic. Phytopathology 26:614–29.
21. ZAUMEYER, W. J., and B. L. WADE.
1933. Mosaic disease affecting different legumes in relation to beans and peas. Phytopathology 23:562–64.

10*m*–5,'38(2061)